field, demonstrating the small divergence of the beam, which was a result of the temperature of the electrons in the beam. The shape the electron bunch generated was not ellipsoidal at all, but rather a cartoon sketch of the structure of the atom (Fig. 1b) as a more striking proof of their ability to generate arbitrary shapes. Indeed, producing ellipsoidal bunches was not crucial here as space-charge effects were too weak to warp their shape at the low charge densities produced. But the technique could be used to generate an ellipsoidal distribution — in two dimensions at least — to counteract such effects at higher densities.

By combining three important properties — extended source area, ultralow electron temperature and arbitrary charge shaping — the source McCulloch *et al.* demonstrate[8] represents a promising step toward enabling ultrafast dynamic processes within molecular structures to be studied by electron diffraction. But substantial further development is still needed to reach this goal. The duration, intensity and average energy of the pulses produced are still far from those needed for ultrafast scattering studies. But these are technical rather than fundamental challenges that could yet be solved. Moreover, even if these sources never reach the extreme fluxes and coherence of X-ray beams produced in an X-ray free-electron laser, they could provide a complementary, inexpensive and more widespread addition to laboratory-scale electron microscopy. ❐

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References

1. Wilkins M. H. F., A. R. Stokes A. R. & Wilson, H. R. *Nature* **171,** 738–740 (1953).
2. Freitag, B., Bischoff, M., Mueller, H., Hartel, P. & von Harrach, H. S., *Microsc. Microanal.* **15,** 184–185 (2009).
3. Dwyer, J. R. *et al. Phil. Trans Roy. Soc. A* **364,** 741–778 (2006).
4. Emma, P. *et al. Nature Photonics* **4,** 641–647 (2010).
5. Siwick, B. J., Dwyer. J. R., Jordan, R. E. & Miller, R. J. D., *Science* **302,** 1382–1385 (2003).
6. Lobastov, V. A., Srinivasan, R. & Zewail, A. H. *Proc. Natl Acad. Sci. USA* **102,** 7069–7073 (2005).
7. Chapman, H. N. *et al. Nature* **470,** 73–77 (2011).
8. McCulloch, A. J. *et al. Nature Phys.* **7,** 785–788 (2011).
9. Luiten, O. J., van der Geer, S. B., de Loos, M. J., Kiewiet, F. B. & van der Wiel M. J. *Phys. Rev. Lett.* **93,** 094802 (2004).
10. Musumeci, P., Moody, J. T., England, R. J., Rosenzweig, J. B. & Tran, T. *Phys. Rev. Lett.* **100,** 244801 (2008).

SEMICONDUCTORS

Electrons surf the wave

Two teams of researchers have succeeded in transporting a single electron from one quantum dot to another using a surface wave (Sylvian Hermelin *et al. Nature* **477,** 435–438; 2011 and R. P. G. McNeil *et al. Nature* **477,** 439–442; 2011). This technology could represent an exciting platform for the transfer of quantum-optics experiments to on-chip infrastructures.

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Quantum information processing using photons is already a well-developed technology — the key to this steady advance being the fact that photons largely ignore each other. This is in stark contrast to electrons, which, when travelling along a wire, interact with one another and quickly lose any quantum information they might be carrying. However, Hermelin *et al.* and McNeil *et al.* have now separately shown how surface acoustic waves can transfer individual electrons over an extended distance while isolating them from their surroundings.

Gallium arsenide is a piezoelectric material: any mechanical expansion or contraction generates an internal electric field and *vice versa*. Both groups of researchers used a metallic transducer to generate ripples on gallium arsenide, creating a corresponding propagating electric field. This surface acoustic wave then picked up an electron as it passed across a single-electron source and transported it along a narrow channel to a distant detector.

A natural choice for both a source and a detector of single electrons is a quantum dot. Its small size, usually of the order of ten nanometres, means that the electron energy levels are discrete, much like those in an atom. Thus, electrons can be isolated, and the addition of a single electron leads to a detectable change in a dot's electrical properties.

Hermelin *et al.* demonstrated a single-electron generation efficiency of 96% and a detection efficiency at the second dot, three micrometres away, of 92%. Such effective processes should aid the scaling up of this basic unit to more complicated circuits. Additionally, McNeil *et al.* were able to shuttle their electron back and forth between two dots as many as sixty times, clocking up a total distance travelled of 0.25 millimetres.

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